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Hybridizing Wheat and Emmer

by Roy G. Wiggans

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Sept. 1915

C.T.

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Introduction

In the crossing of any kind of plants where uniform results are desired it is absolutely necessary to start with uniform parents. Even in pure lines there is always considerable variation. For the work reported in this paper, pure lines of wheat, so far as it is possible to secure them, were used for one parent and for the other a pure line of Black Winter Emmer.

Object

The object of the investigation was: (1) to determine, if possible, any characters that are inherited in Mendelian fashion; (2) to secure new types which might be of value.

Review of Previous Work

The work done with the wheat emmer cross has been in general very unsatisfactory and, like the work reported in this paper, has not been carried to a successful end. C. E. Saunders[I] made reciprocal crosses of Colorado wheat and winter emmer which gave him in F_3 fifteen distinct types where winter emmer was used as the female parent and twelve types where winter emmer was the male parent. The poorest sorts were eliminated and no definite mathematical

study was made. He reports in the same paper a cross of Red Fife Wheat and Polish Wheat which gave many types in F_3, one of which was very similar to spelt. He thinks that few if any of the types can be regarded as fixed in the third generation. Another cross[II] of Polish and common wheats gave many types but very few of F_1 seed grew to maturity.

B. C. Buffum[III] secured what he called a most remarkable series of mules and monstrosities from a supposed mutating type of wheat and a supposed mutating emmer. Intermediate types were absent while almost every known type heretofore produced was present as well as decidedly new types of grain. Types which seemed to indicate reversion were numerous, one of which was the single-seeded spikelet of the monococcum type; another gave the dicoccum type; and another, true Triticum spelta. Buffum thinks that the results indicate a common origin for all forms of wheat.

M.A. Carleton [IV] states that emmer readily crosses with wheat and that the department at Washington, as well as experiment stations, have used spring emmer for the purpose of adding rust resistance to ordinary wheat. Winter emmer should have even a greater value in this phase of wheat improvement.

Carleton[IV] gives the possible lines of improvement by the wheat emmer cross as : (1) Resistance to fungous attacks, (2) drought resistance, (3) increased fertility of the head, (4) non-shattering, (5) stiffness of straw,

and (6) increase of gluten content of the grain.

Material Used

All the work was done in a greenhouse under controlled conditions. The temperature was regulated for the best growth of cereals and water was added when needed. It was necessary at times to fumigate for aphids.

The plants used, as stated above, were from pure lines of the wheats and emmer. The particular wheats used in the crosses were: (1) Red Hussar; (2) Pride of Genesee; (3) Jones Paris Pride; and (4) Early Arcadian. The crosses were made reciprocally so far as the material permitted. The period of flowering varied somewhat, making it impossible at times to get the desired pollen for some crosses.

Table I gives the description of winter emmer and the various wheats used in the crosses.

Table I.

Characters	Winter Emmer	Red Hussar	Pride of Genesee	Early Arcadian	Jones Paris Pride
Awned or Awnless	Awned	Awnless	Awned	Awnless	Awnless
Color of Awn	Black at base to gray at top	x	Light yellow	x	x
No. spikelets per 5 cm.	21	8	10	Clubbed wheat	8
Color of Glumes	Grayish black	Light yellow	Light yellow to white	Similar to Jones Paris Pride	A little darker than Red Hussar
Glumes smooth or velvet	Velvet	Smooth	Smooth	Smooth	Smooth
Glumes loose or adhering closely	Adhering tightly	Loose	Loose	Loose	Loose

The original crosses were made in the summer of 1913. The seeds thus secured were grown together with the parents the following year. In the fall of 1914 the seeds of F_I plants were sown in the greenhouse and parent plants were grown under the same conditions to eliminate any chance of change due to environment. In every case a sample head was saved from the parent plants and where possible seeds of the F_I plants were saved. If this was not practicable photographs were taken so that the record would be complete.

In June of the summer of 1915 the plants of F_2 were harvested, each one separately in order that a study of the various characters might be made on the individual plants.

Method of Crossing

The actual method of making the crosses is very simple. Only a fair knowledge of the floral structures is necessary to make the work a success. After working with the flowers for some time, it was found that it was easier to get the pollen from the wheat to pollinate the emmer flowers than to make the reciprocal cross. However, the crosses were made both ways. The head is first prepared for emasculating by removing the lower spikelets and clipping out the top of the head until only eight or ten spikelets remain. The center flower or flowers of the spikelet are then removed with a pair of forceps. In

wheat there are sometimes two and even more fertile central flowers, but in emmer these are generally sterile. This leaves sixteen to twenty lower flowers on each head. The anthers (three in number) are removed and the flower is left in this condition as a rule for two days. The time varies with the maturity of the flower when emasculated. Care must always be exercised not to injure the flower parts and especially the two-parted pistil.

The heads after emasculation are covered with a semi-transparent bag two inches wide and eight inches long to prevent any possible cross pollination. In the greenhouse it is not necessary to tie the bags on the heads.

When the pistils are mature, that is, receptive to pollen, they have developed a two-parted pistil. Both divisions are very much branched which gives a feathery appearance to the opened flower. At this stage the stigmas have usually begun to show between the palea and the flowering glume. If the flower is not pollinated, the glumes begin to spread apart exposing the pistil not only to its own pollen but to any pollen that might be carried to it. This is the most advantageous time to pollinate as the stigmas are most receptive at this stage and a greater percentage of grain will be secured. The pollen to be effective should be ripe. Anthers that are opening are the best, but if they cannot be found, anthers which are very yellow must be used. Some of these will soon open and shed their pollen. In this way all the anthers

that are gathered are covered with ripe pollen. It is advisable to place a whole anther in each flower that is to be pollinated. Pollen grains are all that is necessary if properly placed on the stigma of the flower. Pollination is accomplished by carefully opening the flower either with forceps or by gently pressing the upper end of the glumes with the left forefinger while holding the base firmly and placing ripe anther on the stigma.

There are many circumstances that mitigate against success in this work, but with sufficient care crosses can be secured in either direction with all the varieties reported in this paper. Crosses with wheat and emmer are considerably more difficult than wheat crossed with wheat. This is probably explained by the fact that emmer is some distance from wheat speaking from the standpoint of evolution, but we would assume that it is closer than rye as crosses with rye are very difficult to secure and all that have been reported are sterile.

The success of the crosses herein reported may be given briefly as follows:

Cross				No. of kernels
Winter emmer		x	Early Arcadian	37
"	"	x	Pride of Genesee	55
"	"	x	Jones Paris Pride	9
"	"	x	Red Hussar	33

The reciprocal crosses are given together as there was no difference in the results whichever way the cross was made. The heads pollinated varied from a complete failure to sixty-five per cent set. In the care of wheat x wheat a large percentage was very common, fifty to sixty per cent being the average with an occasional percentage as high as ninety.

The seeds secured from the crosses were planted together with parent plants as before stated. The characteristics of the F_1 plants produced from the above seed are given in Table II.

Description of First Generation Crosses

Table II.

Characters	Jones Red Mane X Black Winter Emmer	Early Arcadian X Black Winter Emmer	Red Hussar X Black Winter Emmer	Pride of Genesee X Black Winter Emmer
Awned or awnless	Intermediate	Intermediate	Intermediate	Awned
Color of awn	Dark gray	Gray	Light gray	Light gray
No. spikelets over 5 cm.	10	Clubbed	12	12
Color of glumes	From almost as dark as emmer to very light	Little darker than Red Hussar	(Intermediate) dark gray	Varying from almost as dark as emmer to much lighter
Glumes (smooth or velvet	Smooth	Smooth	Smooth	Smooth
Glumes (loose tight	Intermediate	Intermediate	Intermediate	Intermediate

Table II gives the average results of F_1, which indicate in some way what has previously been demonstrated in wheat crosses.

Beardedness in F_1 is an intermediate character. The results of Biffen[VI] lead one to conclude this although he classes beardedness as recessive. He fails to count in the bearded class the heads which are only slightly bearded but places them in the class with the beardless. It is probable all the results that have been obtained are similar in regard to the beardedness being recessive but the interpretation has been different. Wilson[VII] like Biffen reports that awnlessness is dominant, giving 664 awnless and 207 awned. Bateson[VIII] also reports the same thing but upon observation of the illustrations given, it can be seen that some of those which he calls beardless possess beards, varing in number and length. A like statement can be found which was made by Punnet[IX]. He fails to give any data to support what he assumes as a fact, probably in part because he uses it only as an argument for a theory which he was presenting. The work of Alvin Keyser[X] shows very conclusively that the result when bearded and beardless types are crosses is an intermediate product. This is not based upon one cross but upon many crosses and as his observations were upon the one character they probably represent very accurately what really existed. In F_2 he found practically 25 bearded; 50 intermediate; 25 beardless, the actual per cents being 21 bearded,

53 intermediate and 26 beardless. Both the awned and awnless bred true in F_3.

The inheritance of beardedness is an unsettled question and offers a very good opportunity for an accurate and detailed statistical study from a Mendelian standpoint.

The color of awns is a character which is probably intermediate in F_1. There is, however, scarcely sufficient evidence to support this statement.

The record of the inheritance of laxness or denseness in the ears seems much more conclusive. F_1 has practically the same head, so far as laxness is concerned, as does the parent with the laxer head. Biffen[VI] reports that loose heads are dominant to compact heads.

W. H. Parker[XI] in a rather extensive report of "Lax and Dense-eared Wheat" finds the problem of inheritance of denseness and laxness a very complex and entirely unsettled one. His results are conflicting and definite conclusions cannot be drawn from them.

Prof. Spillman[XII] reports 14 crosses of dense and lax wheats with the result of 1 lax; 2 intermediate; 1 dense. His actual percentages were 27.2; 47.2; 25.6. The different varieties gave very different results but the above percentages are the average of all his crosses.

Nilsson-Ehle[XIII] finds a 1:2:1 ratio in F_2 with dense and lax-eared wheats.

Sufficient evidence is not given in F_1 of the crosses reported in this paper to indicate accurately how the color of glume is inherited.

All the heads in F_1 were smooth but it is possible that a microscopic examination would have shown velveting of the glumes. Biffen[VI] reports velveting to be dominant. The studies in F_2 indicate that this is the case.

In F_1 the tightness with which the glumes adhered to the kernels was intermediate in character. A detailed study of this was not made on F_2 plants. A very profitable study could be made on this character as the shattering of wheat is a serious problem in some districts where the grain is permitted to become very ripe before harvesting. A wheat with a glume that adhered more closely would be much more desirable than the ones now grown if this character could be combined with the desirable characters already possessed by the present wheats.

The following photographs show characteristic heads of the wheats and emmer used. The heads of the parent stocks used for the crosses are shown together with a head of the F_1 plants. Some of the characters described above are apparent in the photographs.

Fig.1. Heads of parent plants with the F_1 cross.
1256 X Jones Paris Pride.
1256 A F_1 cross.
1256 Y Black Winter Emmer.

Fig. 2. Heads of parent plants with the F_1 cross.
1260 X Black Winter Emmer.
1260 A F_1 cross.
1260 Y Early Arcadian.

Fig. 3. Heads of parent plants with F_1 cross.
1252 X Pride of Genesee.
1252 A F_1 cross.
1252 Y Black Winter Emmer.

Results of Second Generation

The grain of the F_1 plants was sown and the F_2 plants grown and harvested separately. The results as they come out in the individual plants are very confusing but some characters could be studied very accurately. The inheritance of the color in the glumes comes out in a very good Mendelian ratio of 3:1, the actual numbers being 179 black; 53 white. In the blacks were included all shades and degrees of blackness from the color of emmer to the slightest indication of the presence of a color factor. All shades could be found in every cross where there were sufficient numbers.

The bearded character gave 87 bearded; 90 intermediate :::::: 64 beardless. If the bearded and intermediates are grouped together 177 bearded : 64 intermediates or a 3:1 ratio, results but no indication as to dominance of beardlessness over beardedness.

The velveting character was not studied on all the crosses but particular care was given it in the cross between Red Hussar x Black Winter Emmer. In this cross there seems to be two factors which control the inheritance of the hairs. The Red Hussar type has hairs at the base of the spikelet but the glumes are free while the Winter Emmer used had hairs on the glumes but the base was free. It was often necessary to use a strong lens to determine the presence of the hairs. The ratio secured was:

35 with hairs at base and on the glumes.

25 with hairs at base only.

23 with hairs on the glumes only.

3 with no hairs.

The same thing studied with a cross of Mediah and Minnesota Wheat #169 gave the ratio 56:29:25:2. Both made very poor 9:3:3:1 ratios but they give sufficient evidence to show that there is a segregation of two characters and that they are inherited independently. The shape of kernel, shape of glume, and texture of glume were inherited independently but were not studied especially for segregation. The emmer textured glume seemed to be dominant. By texture is meant the stiffness and coarseness of the glumes.

Various Types of Heads in F_2.

So far as a segregation of types is concerned it is very difficult to get any ratios or any definite classes. In order to make a study of the F_2 plants they were arranged in groups with characteristic differences. The groups were named (1) Emmer type, (2) Spelt type, (3) Emmer spelt, (4) Spelt wheat, and (5) Emmer wheat. Those which did not fall into these arbitrary groups were placed in a sixth group which was made up of all kinds and shapes of heads most of which were clubbed. The names of the groups explain more or less the characters of the heads of the plants placed in them. Likewise the photographs illustrate their general characteristics. In each group were found both black and

white, and beardless and bearded except in groups (1) and (3) where no beardless types appeared.

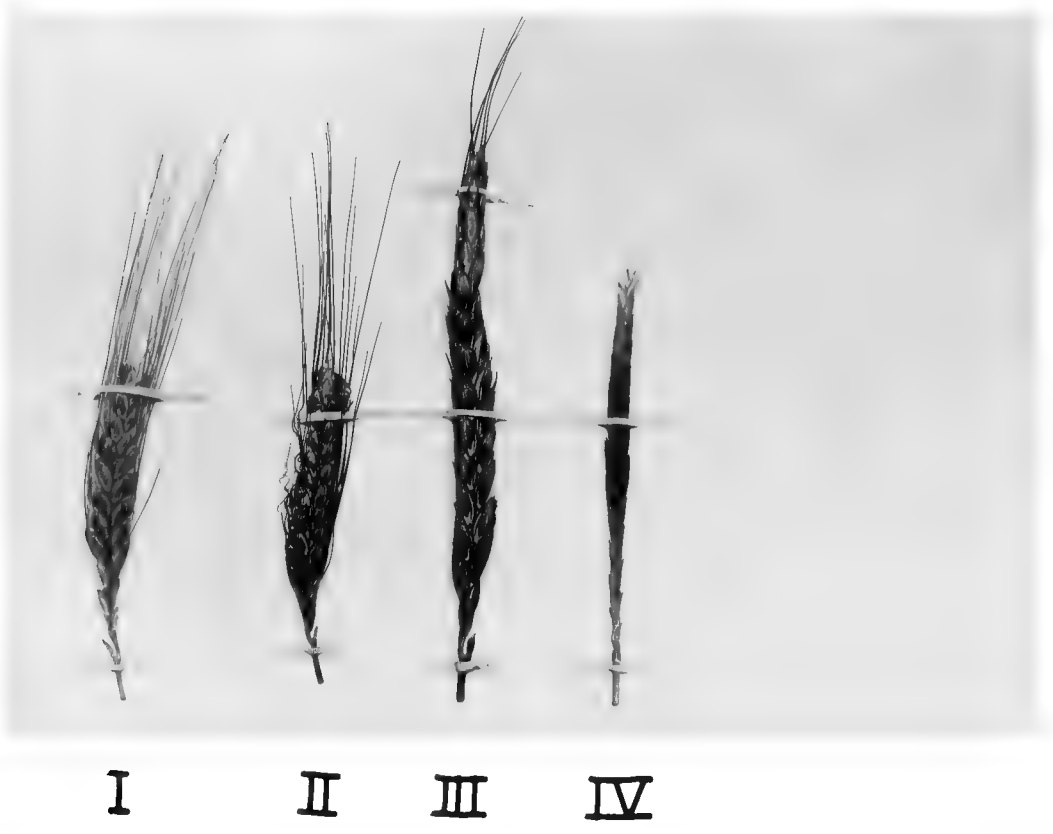

Fig. 4 Emmer types : I White bearded, II Black bearded, III Intermediate black bearded, IV Black beardless.

Fig. 5. Spelt types: I Black bearded; II Intermediate bearded black; III Black beardless; IV White bearded; V White intermediate bearded; VI White beardless.

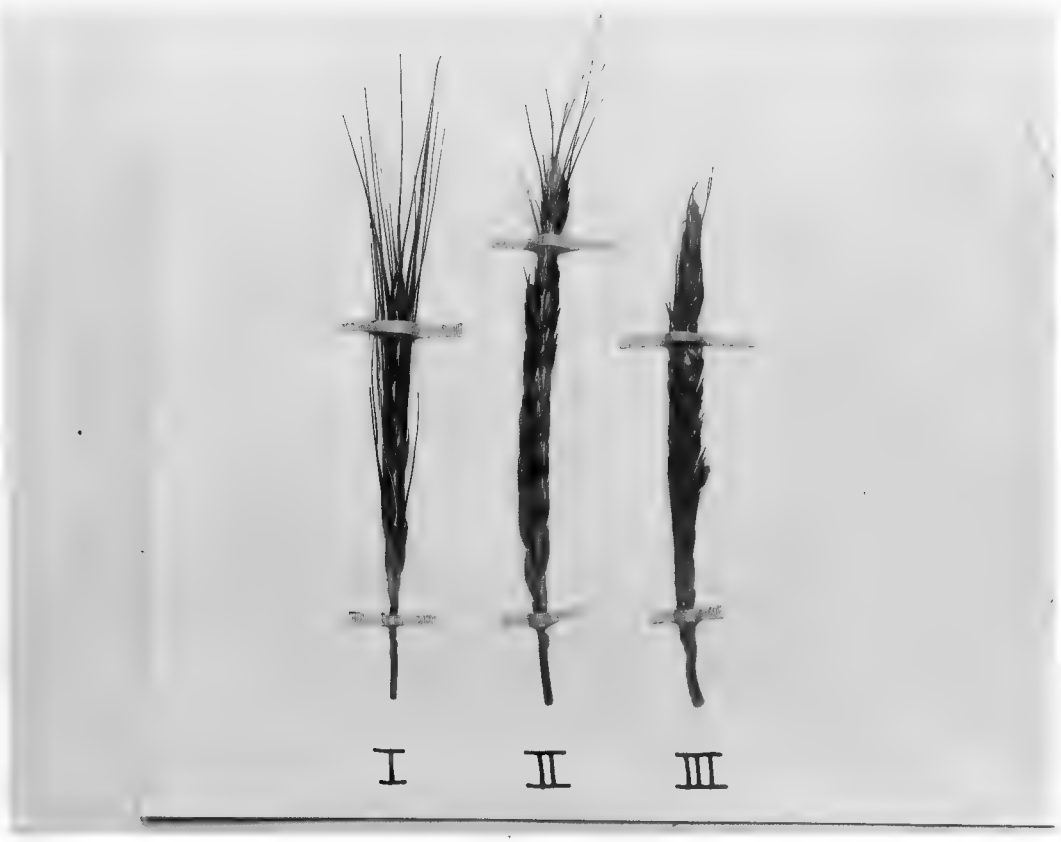

Fig. 6. Emmer spelt types: I Black bearded;
II Black intermediate bearded;
III White intermediate bearded.

Fig. 7 Seplt wheat types: I Black bearded; II Black intermediate bearded; III White bearded; IV White intermediate bearded.

Fig. 8. Emmer wheat types: I Black bearded; II Black intermediate bearded; III Black beardless; IV White bearded; V White intermediate bearded.

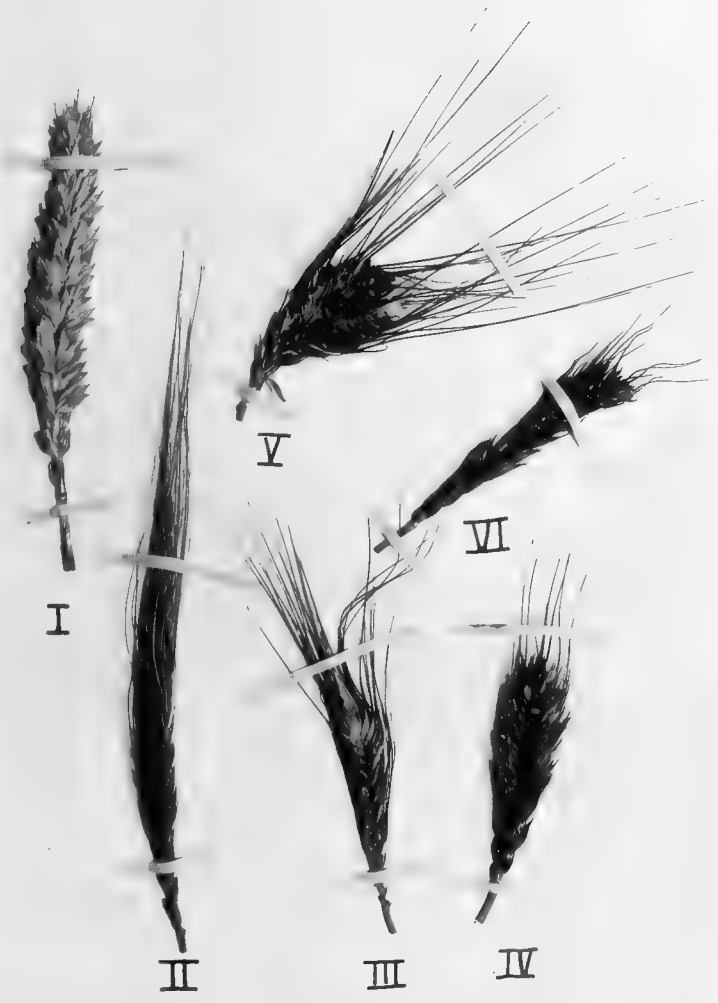

Fig. 9. Heads of unclassified plants;
I Wheat type; II Einkorn type;
III, IV, V, and VI Club types.

Fig. 10 Heads of unclassified plants continued: VII-X all club types most of which are sterile.

Table III.

	Jones Paris Pride	Early Arcadian	Red Hussar	Pride of Genesee	Total
Black chaff	36	11	61	10	179
White chaff	6	3	22	3	53
Bearded	15	5	25	13	87
Intermediate Bearded	16	5	37	0	90
Beardless	11	4	24	0	64
Emmer Type (Bearded Black	3		5	0	8
Emmer Type (Bearded White	1		0	0	1
Emmer Type (Beardless Black	0		0	X	0
Emmer Type (Beardless White	0		0	X	0
Spelt Type (Bearded Black	3	1	3	1	12
Spelt Type (Bearded White	0		1	0	4
Spelt Type (Beardless Black	6		1	X	11
Spelt Type (Beardless White	0		1	X	3
Emmer Spelt (Bearded Black	4	2	5	2	17
Emmer Spelt (Bearded White	1		1	0	3
Emmer Spelt (Beardless Black	0		0	X	0
Emmer Spelt (Beardless White	0		0	X	0
Spelt Wheat (Bearded Black	1		5	1	14
Spelt Wheat (Bearded White	0		0	0	2
Spelt Wheat (Beardless Black	0		2	X	2
Spelt Wheat (Beardless White	0		0	X	1
Emmer Wheat (Bearded Black	6	4	16	3	36
Emmer Wheat (Bearded White	2	2	13	2	21
Emmer Wheat (Beardless Black	1	2	11	X	14
Emmer Wheat (Beardless White	0	1	3	X	4
Wheat Type)-Black bearded		2			2
Wheat Type) Velvet)	29				
Wheat Type) Glabrous)	13				
Not classified only as clubs	8	0	19	14	41

H_1-B_{11})Both clubbed
H_1-A_1)but classed as emmer wheats.

Table III gives the distribution in the various classes of the F_2 plants of the four crosses studied. The unclassified group illustrated by Figures 9 and 10 represent a great variety of forms varying from einkorn to true wheat as well as the vaious clubbed forms.

Conclusions

1. That in any cross of wheat and emmer there is obtained in F_2 a series of forms which resemble einkorn spelt, emmer, common wheats, and club wheats.

2. That no definite Mendelian segregations were found as to form of head.

3. That the characters beardedness, color of glume, and velveting are inherited in Mendelian fashion.

4. That large numbers would have to be studied through a series of years before any accurate conclusions could be drawn.

ACKNOWLEDGMENT

The writer desires to thank Dr. H. H. Love for his directions and kindly assistance in the study reported above and for the material which made it possible for the work to be done.

References

I. Saunders, C. E.
1905 Some observations on heredity in wheat.
A.B.A. Vol.I, pp. 77-78.

II. _____
1905 A natural hybrid in wheat.
A.B.A. Vol. I, pp. 137-138.

III. Buffum, B. C.
1909 Effect of environment on plant breeding.
A.B.A. Vol. VI, pp. 212-225.

IV. Carleton, Mark Alfred.
1911 Winter Emmer.
U. S. Dept. of Agr. Farmers Bul. 466.

V. _____
1901 Emmer: A grain for the semiarid regions.
U.S.Dept. of Agr. Farmers Bul. 139.

VI. Biffen, R. H.
1905 Mendel's laws of inheritance and wheat breeding.
Jour. of Agr. Sc. Vol. I, pp. 4-48.

VII. Wilson, John H.
1907-08 The hybridization of cereals.
Jour. of Agr. Sc. Vol. II, pp. 68-88.

VIII. Bateson, W.
1909 Mendel's principles of heredity.

IX. Punnet, R. C.
1911 Mendelism.

X. Keyser, Alvin.
1906 Variation in wheat hybrids.
A.B.A. Vol. 2, pp,84-89.

XI. Parker, W. H.
1914 Lax and dense-eared wheats.
Jour. of Agr. Sc. Vol. VI, pp. 371-386.

XII. Spillman,
1902
Journ. Royal Hort. Soc. XXVII, p. 876.

XIII. Nilsson-Ehle
Lunds Universitets Arsskrift, N.F.
a.f.d. 2, Bd.V, Nr.2, p. 104 et seg.